48. *The* Precambrian Rocks *of* Shropshire.—Part I. By C. Callaway, Esq., M.A., D.Sc. Lond., F.G.S. *With* Notes *on the* Microscopic Structure *of some of the* Rocks, by Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S. (Read June 11, 1879.)

Contents.

Introduction.

In a paper communicated to this Society on March 21st, 1877, entitled "On a new Area of Upper Cambrian Rocks in South Shropshire"*, I intimated that certain volcanic rocks associated with the shale in question, which had been usually regarded as eruptive greenstones, were for the most part composed of bedded material; but details were deferred.

Mr. S. Allport, in a paper "On certain Ancient Devitrified Pitchstones and Perlites from the Lower Silurian District of Shropshire"†, read before this Society in May 1877‡, announces the same conclusion from entirely independent observations, devoting his attention, however, chiefly to the chemical and microscopic side of the question, and arriving at the very important conclusion that these (so-called) Lower Silurian pitchstones and perlites are identical in character with the most modern volcanic rocks.

In June 1878, I read to this Society a paper on "The Quartzites of Shropshire"§, in which I gave several sections across the Wrekin volcanic chain, and assumed that the bedded rocks of which it is mainly composed were of Precambrian age.

Messrs. Hill and Bonney, in their second paper "On the Precarboniferous rocks of Charnwood Forest" ||, infer the same conclusion

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 652. † *Ibid.* vol. xxxiii. p. 449.

‡ Both Mr. Allport and myself had contemporaneously announced this fact to the Birmingham Natural History Society, and he informs me that it was known to him nine years ago.

§ Quart. Journ. Geol. Soc. vol. xxxiv. p. 754. || *Ibid.* vol. xxxiv. p. 236.

from my determination of the (at least) Upper Cambrian age of the quartzites which flank the Wrekin axis.

It is proposed in the present paper to describe the lithological and stratigraphical character of these rocks, and to state in full the evidence for their Precambrian age. In a subsequent communication an attempt will be made to trace the physical history of this Precambrian mountain-chain, to describe the association of the bedded rocks with subsequent eruptive greenstones, and to correlate the Precambrian groups of Shropshire with other known formations. The recent recognition by the author of the Lilleshall Precambrian rocks on the eastern flank of the Malvern Hills*, and of the Malvern schistose types at the base of the Wrekin series, has an important bearing on the last inquiry; but details are, for the present, reserved.

I have to acknowledge my great obligation to Prof. Bonney, F.R.S., for his invaluable and willing aid in working out some difficult points in lithology. Mr. Allport's paper on the Wrekin, already referred to, has also been of great assistance.

A. Physical Geography of the Wrekin and Caer Caradoc Chain.

In Shropshire, this chain of hills is twenty-nine miles in length from N.E. to S.W.; but, if we include in it the elevations west of Kington, in Herefordshire and Radnorshire, which are probably in part composed of rocks of the same series, the line will reach nearly fifty miles. These hills do not form an unbroken range, but are here and there separated by broad intervals of comparatively level ground. The more typical forms are triangular in transverse section, and semilunar viewed from the N.W. or S.E., the greater length lying in the general direction of the chain. They are easily distinguished from the round-backed elevations of the Longmynd on the N.W., and from the ridges of the Caradoc Sandstone on the S.E., by their abrupt slopes and conical forms. They constitute a median axis, on each side of which run several parallel ridges with their escarpments facing towards it. On the west is the Longmynd range, succeeded at a distance of six miles by the abrupt edge of the Stiper Stones. On the east appear in succession the parallel elevations of Hoar Edge, the Chatwall ridge, and, at a greater distance, the sharp escarpment of Wenlock Edge, overtopped by the less angular and less regular ridge of the Aymestry Limestone. Most of the flanking ranges lie in comparatively unbroken straight lines, and fall down steeply on the side looking towards the Precambrian axis; while the axial rocks themselves present a cone or boss at intervals only, and slope abruptly and evenly to both south-east and north-west.

The following are the principal elevations, commencing at the north-east end of the chain :—

* Messrs. Hill and Bonney, Quart. Journ. Geol. Soc. vol. xxxiv. p. 237, note §, also recognize a second Precambrian group at Malvern.

a. *The Wrekin Group.* Lilleshall Hill, Ercal, Lawrence Hill, the Wrekin, Primrose Hill.
b. *Caer Caradoc Group.* The Lawley, Caer Caradoc, the Ragleth, Hope Bowdler Hill.
c. *Horderley Group.*
d. *Kington Group.*

B. Lithological and Stratigraphical Characters of the Rocks.

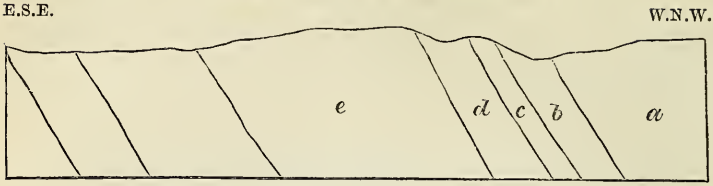
1. *Lilleshall Hill.*

This elevation is coloured on the survey map as "altered Caradoc," with a central boss of "greenstone." I have seen no trace of greenstone or any other intrusive rock in the hill. The supposed Caradoc is of Precambrian age.

Details.—At the S.W. end, in the road just below the village, is a hornstone of dark grey colour mottled with red. This is overlain, in a small opening immediately to the S.W. of the large quarry, by a grey thin-bedded ashy slate, with oval steatitic blotches on the planes of lamination, dipping N. 10° W. at 23°. In the great quarry there is a fine exposure of similar strata, much altered. Felspathic and steatitic matter are separated in the decomposition, and give in places a beautifully variegated appearance to the rock, pink and green colours predominating. Here and there the felspar has segregated in clusters and layers of red crystals. Some of the ashy beds are white and less altered. The general dip is N.N.W. at 30°. At the N.E. end of the quarry there is an interesting junction of the softer beds with an overlying hornstone. The latter is very hard and compact, approaching a hornstone; while the former, in immediate contact with it, is so soft as to be easily scratched by the nail. In this place the ashy rock is very ferruginous, the iron peroxide separating in little round nests. The beds dip at 40°. The hornstone cannot be far from the horizon of a massive hornstone band which stands out as a craggy boss crowning the hill, and is probably the "greenstone" of the Survey. N.E. of the summit, we have a repetition of grey ashy beds, dipping N. 10° W. at from 40° to 50°, succeeded by a felspathic breccia, composed of fragments of Wrekin rhyolite in a grey matrix. Some of the fragments show the characteristic banded structure. Breccias are abundant on the S.E. slope. The highest beds, clearly exposed in a long section at the N.E. end of the hill consist of alternations of ashy beds and hornstones, similar to those described, as represented in fig. 1.

In this section the ashy bands are very clearly separated from the hornstones. The beds *b* and *d*, for example, each about 10 feet thick, are soft and ferruginous, and have been excavated by weathering to a considerable depth; while the band *c*, 5 feet thick, composed of hornstone precisely similar to the rock at the N.E. end of the great S.W. quarry, stands out like a sharp wall.

Fig. 1.—*Section across N.E. end of Lilleshall Hill.*



a, c, e. Hornstone. *b, d.* Ash.

In a series of rocks from Charnwood Forest I have observed a slate which suggests, though it is quite distinguishable from, the grey slate S.W. of the large quarry. Prof. Bonney has also noticed this resemblance.

On the N.W. side of Lilleshall Hill are faulted beds of Bunter Sandstone; and on the S.E. the Hollybush Sandstone is thrown down. On the N.E. the axis of the ridge is prolonged under the Carboniferous Limestone, which is bent into an arch by the subsequent elevation of the Precambrian axis. To the S.W., a S.W. line of fault, Bunter Sandstone against Coal-measures, connects Lilleshall Hill with the Wrekin, and the axis is undoubtedly continued under the younger formations.

Summary.—A S.S.W. ridge, composed of alternations of hornstone and ashy slates and shales, with felspathic agglomerates in the middle. Average dip of 40° to N.N.W. Minimum thickness 1500 feet. Bounded by two nearly parallel faults, converging at each end, Bunter Sandstone being thrown down on the N.W., Hollybush Sandstone on the S.E.

2. *The Ercal* (figs. 4 & 5, p. 650).

Details.—On the N.W. slope of this hill, just overlooking the town of Wellington, is a large quarry, distinguishable for miles by the colour of the bright red felspathic rock of which the exposure chiefly consists. Near the surface this rock is divided by very close joints, and it is easily shovelled away as gravel. It forms a broad zone, striking E. and W. across the face of the quarry. It is underlain by a grey or greenish-white rock, forming a zone parallel to the upper red band for the entire breadth of the section. The dip of the red rock is apparently to the S., that is, opposite to the prevalent dip of the Wrekin chain. Following this rock from the N.E. end of the Ercal, just above the quarry, along the ridge to the S.W., we come in about half a mile to a sudden change. The red rock abruptly gives place to a compact felstone, dipping N.N.W. at 50°, which is exposed in a buttress which supports the ridge on the N.W., and still more conspicuously in the broken crags at the S.W. end of the hill.

It might, at first sight, seem as if the Ercal were composed of beds lying in a synclinal; but the great difference between the rocks at the opposite ends appears to negative this supposition. I

believe that the ridge is cut across by a fault. This view is supported by the abrupt change in lithological characters. At the point of junction the ridge is cut into by a ravine on the N.W. slope. The felstone spur forms one side (S.W.) of the hollow, and on its N.E. curve the red rock breaks up through the soil.

The red rock is granitoid in character and probably of clastic origin. (See Note B, p. 664.) Its rectilinear junction with the grey rock seems to negative the supposition of an amorphous mass.

The grey band is uncrystalline, much jointed, and very variable in colour and hardness. To the naked eye, it looks very much like a tuff, containing fragments of the characteristic Wrekin rhyolite, some of which are distinctly banded. Some of the included bits are rounded, like pebbles. Prof. Bonney is, however, clearly of opinion that this singular rock is simply another form of the Wrekin rhyolite intrusive in the red rock. (Note A, p. 663.) This revelation by the microscope is very interesting and important, and will be a great aid in correlation.

Along the S.E. flank of the hill strike the thick beds of quartzite, succeeded by the Hollybush Sandstone and the Shineton Shales, described in previous papers *. The quartzite probably holds the same position on the N.W. of the axis, but exposures are very scanty.

Summary.—A S.W. ridge composed of a bedded granitoid rock dipping southerly, and underlain by eruptive Wrekin rhyolite, at the N.E. end, and of grey and brown felstones with a N. dip for the remainder of its length, the two series being separated by a fault, the ridge being flanked by quartzite on the N.W., and by quartzite, followed by Cambrian strata, on the S.E.

3. *Lawrence Hill* (figs. 2, 4, 5).

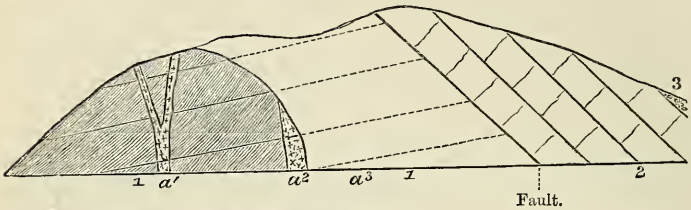
Details.—The north-east end is composed of felstones similar to the opposite crags of the Ercal, and felstone may be traced all along the crest of the hill till we reach the edge of the great quarry, which exposes a considerable part of a transverse section of the chain. It was this magnificent exposure which first convinced me of the erroneous interpretation of the Survey. This supposed eruptive greenstone consists of felspathic tuff †, clearly bedded, and dipping north at 50°. The true bedding is much obscured by jointing, but it may be made out most satisfactorily by following beds to the right or left. Continuity of texture is thus as clear a proof of stratification as continuity of mineral composition in ordinary sedimentary rocks. The bands vary from a fine-grained ash to a breccia or a conglomerate. Even hand specimens sometimes distinctly show alternations of fine and coarse bands. In addition to this evidence of stratification, the seams separating beds and the exposed surfaces of the beds themselves are clearly visible. The coarser bands contain fragments of pitchstone and of felstone, the

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 652, and vol. xxxiv. p. 754.

† Described by Mr. S. Allport, Quart. Journ. Geol. Soc. vol. xxxiii. p. 458.

latter sometimes displaying the characteristic banding of some of the Wrekin felstones. Fig. 2 shows the structure of the chain at this point.

Fig. 2.—*Section through Lawrence Hill.*



1. Bedded Precambrian tuff, dipping north.
2. Quartzite.
3. Hollybush Sandstone.

a^1, a^2, a^3. Dolerite dykes. The position only of a^3 is indicated, and only so much of a^2 as is actually exposed is drawn.

The shaded portion represents the strata exposed in the quarry. The continuation of the bedding beyond the quarry is indicated by the broken lines. The beds plunge into the face of the quarry obliquely, so that the section is taken at an acute angle with the dip, and the true dip is not shown. The dyke a^1 is well exposed, and, in its lower part, stands out like a wall. The dolerite is fine-grained, and may be called basalt. It is considerably altered, calcite being deposited in the cracks, and the tuff in the vicinity of the dyke has also undergone more than its usual alteration. The changes in both cases I conceive to be due to the infiltration of carbonated waters subsequently to the injection of the basalt, the dislocation allowing passage to the water more freely than the unbroken strata. The altered tuff in proximity to the Lawrence-Hill dyke contains greenish matter, apparently some form of magnesian silicate, one of the commonest products of wet chemical decomposition. The surface of the dyke in contact with the tuff is minutely jointed into rectangular prisms an inch or two square, and lying with their long diameters at right angles to the bounding surface. I have detected two of these dykes, apparently a^2 and a^3, on the Wrekin side of the ravine, in the road up to the cottage, and striking towards a mass of dolerite which protrudes at the surface within half a mile to the south-west in the summit ridge of the Wrekin.

Fig. 2 also shows that on the south-east the tuff is overlain at a considerable angle by beds of quartzite, the former dipping north, the latter south-east. The quartzite is succeeded by the Hollybush Sandstone, and the Hollybush Sandstone by the Tremadoc Shales of Shineton. The planes separating all four formations from each other are probably strike-faults. The quartzite also occurs, but inconspicuously, on the north-west side of Lawrence Hill, dip undetermined.

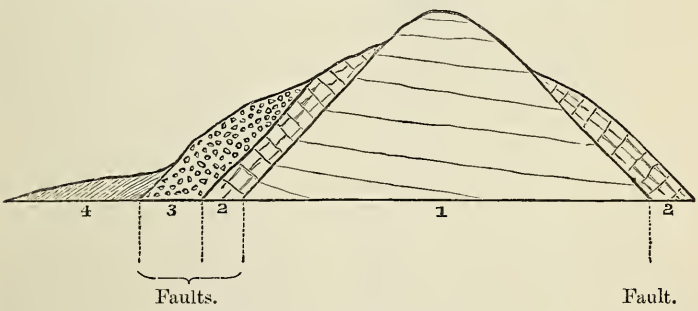
Summary.—A south-west ridge, composed mainly of felstone, but displaying at the south-west end a considerable thickness of

altered felspathic tuff, dipping north at 50°, and cut through by three basaltic dykes, which strike towards a mass of dolerite in the Wrekin. The ridge is flanked by quartzite on both sides, the beds on the south-east being succeeded by the Hollybush Sandstone and the Shineton Shales.

4. *The Wrekin* (figs. 3, 4, 5).

Details.—At the north-east end of the hill, opposite the great quarry in Lawrence Hill, there are numerous exposures of dark grey and reddish tuff, similar to the Lawrence-Hill series. In a large opening at the foot of the ascent, the tuff beds are pushed out into a rounded anticlinal spur. This contortion appears to be due to the intrusion of the mass of dolerite to which reference has been made. Two of the three Lawrence-Hill dykes are also visible on this side of the ravine; and it is evident that both the contortion and the dykes are due to the same cause. Between this point and the dolerite mass the tuffs are somewhat disturbed, the dip being pushed round to 20° west of north. Near the cottage the tuff is a breccia, which is sometimes conglomeratic, the pebbles consisting of felstone, pitchstone, and less frequently of quartz. The subjoined section shows the lie of the tuffs which compose the north-east end of the Wrekin, with their relation to the flanking deposits.

Fig. 3.—*Section across the Wrekin, north-east end.*



Scale about 8 inches to 1 mile.

1. Bedded Precambrian volcanic tuff, dipping north.
2. Quartzite (probably Precambrian).
3. Hollybush Sandstone.
4. Shineton Shales (Tremadoc).

Ascending the hill above the cottage, we reach a round bare hump, the exposed apex of the greenstone mass*. It is composed of dark green dolerite, which in some parts is agglomeratic, in others amygdaloidal, with nuclei of calcite. In its colour, state of decomposition, and in all other respects this rock resembles the dykes of Lawrence-Hill quarry, with which it is undoubtedly connected. It would appear to have been an ancient volcanic vent. It is the only greenstone found in the entire Wrekin chain †.

* First noticed by Mr. Allport in the paper to which reference has been made.

† I have since detected greenstone at the S.W. end.

Fig. 4.—*Longitudinal Section of the Wrekin Chain.* (Scale $2\frac{1}{4}$ in. to 1 mile.)

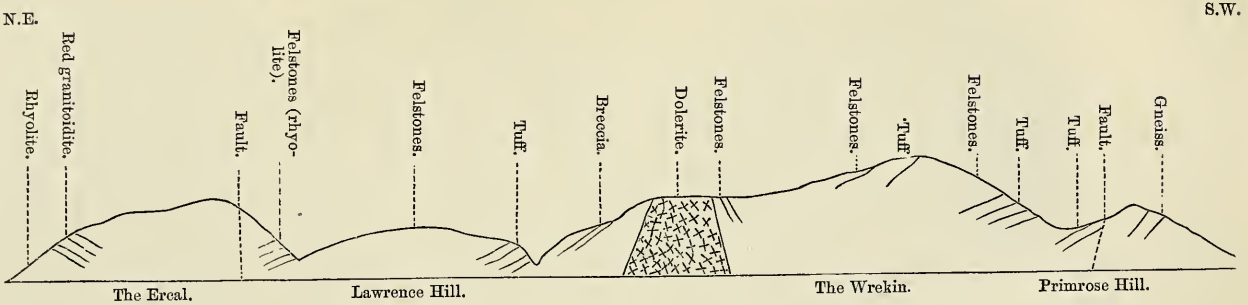
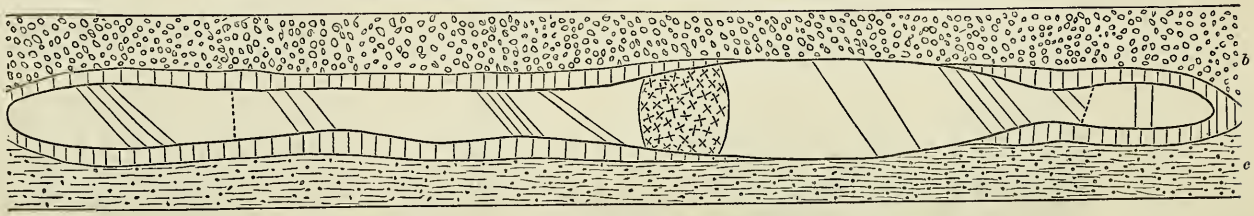


Fig. 5.—*Ground-plan of the same, the Dips in fig.* 4 *being converted into Strikes.*



a. Quartzite. *b.* Hollybush Sandstone. *c.* Trias.

Following the ridge to the south-west, we come to a reddish felstone, the dip of which has been locally reversed by the disruptive greenstone. This rock is continued for some distance. In places it is clearly banded into laminæ of various colours, an alternation of dark chocolate with buff bands being the commonest variety. The laminæ are sometimes contorted like the gnarled wood of an ancient oak.

These Precambrian lavas are underlain near the summit by a greyish agglomerate, with fragments of brown felstone. The dip is northerly.

At the summit and for some distance beyond is a considerable exposure of reddish and chocolate-coloured felstone.

In the middle of the south-west slope, with the normal east and west strike, is a dark coarse tuff, undistinguishable in appearance from the beds near the cottage at the north-east end.

Below the tuff we come to a compact red felsitic rock, underlain, in the saddle between the Wrekin and Primrose Hill, by typical agglomerate.

Relations of the Wrekin axis to the flanking deposits.

The volcanic rocks of the chain are fringed by quartzites *, which in every observed case (with one exception) dip away from the axis at an average of 45°. The exception is on the north-west side of the ravine, between the Ercal and Lawrence Hill, where the beds are nearly vertical, the dip being towards the axis. The base of the quartzite is brecciated, and the junction is evidently a fault. Towards the base the quartzite contains rounded fragments of banded felstone, similar to some of the Wrekin felstones. The quartz rock is clearly younger than the axial rocks, and has been thrust up and thrown off on every side by the upheaval of a rigid wedge of the older series. Under the summit on each side, as shown in fig. 5, the quartzite appears to be absent; and it is presumed that the crest of the Wrekin was an island in the Precambrian ocean, and by its partial denudation furnished the felstone fragments imbedded in the quartzite. On the north-west the Bunter Sandstone is faulted down against the quartzite. On the south-east, the quartzite is succeeded by the Hollybush Sandstone, and the Hollybush Sandstone by the Tremadoc shales of Shineton, the junctions in both cases being parallel lines of fault.

Figs. 4 & 5 will illustrate the series just described. Fig. 4 is a longitudinal section through the chain from end to end. The dips are not fully filled in, only those being indicated which are ascertained with reasonable certainty. The quantity of dip cannot be shown, the section, as in the transverse section, fig. 3, being taken at an acute angle with the dip. The underground extension of the dolerite neck is, of course, hypothetical; it should be represented, if the space permitted, as sending off three dykes to the north-east. Fig. 5 is more instructive, since the true direction of the strikes is shown, and the relations of the flanking formations are indicated.

* Described in Quart. Journ. Geol. Soc. vol. xxxiv. p. 754.

Summary.—The Wrekin is a S.W. ridge, composed of alternations of bedded felspathic lavas and tuffs, with an average dip of 40° to the N. and a little to the W. of N., broken through and disturbed in one place by a mass of greenstone sending off dykes to the N.E., and flanked on both sides by quartzites, which on the S.E. are succeeded by the Hollybush Sandstone and the Shineton Shales.

5. *Primrose Hill.*

The Wrekin tuff is continued through the saddle connecting this spur with the Wrekin mass, and appears on the northern slope near the summit. The chief part of the hill is composed of rocks of an entirely different type. On the S.W. slope, about twenty yards below the top, crops out a band of schistose rock dipping to the N.E. at 55°. It is a very quartzose granulite, the quartz being sometimes quartzite, and the felspar is like the red variety in the Ercal quarry. It is very irregular in composition, passing frequently into hornblendic gneiss, and sometimes approximating to a quartzite with a little red felspar. The W. and S.W. slopes are occupied with granitoidite *, which appears to Prof. Bonney and myself identical with the red rock of the Ercal (Note C). On the N.W. side crop out numerous exposures of a compact rock, which Prof. Bonney has determined to be clastic and similar to hornstone. Some eruptive rocks break out in a few places. Amongst these I have observed a diorite, undistinguishable from a specimen in my collection from Malvern; and Prof. Bonney confirms this view (Note C, p. 665). Some of the granitoidite also is of the Malvern type, showing the red felspar and the small nests of mica, sometimes in a decomposed state, characteristic of the granitic type which I have from the Wych and the North Hill. In both localities there is also the same tendency to pass into hornblendic rock. The strike of the beds is also the same. On the whole, I have no hesitation in identifying the Primrose-Hill rocks with the Malvernian system. Further attempts at correlation are postponed to a future paper. The Wrekin tuffs are in contact with the older schists N.E. of the summit of Primrose Hill, and the plane of separation is undoubtedly a fault. The discordance of strike between the two groups suggests a considerable unconformity.

6. *The Wrockwardine mass.*

Details.—The prevailing rocks of this area are purple and green felstones and breccias. At the village of Wrockwardine, green is the predominant colour. In one or two spots a greenish dolerite, highly decomposed and containing free calcite, has pushed its way up to the surface. In the lane leading from the village towards Cluddley are several exposures of rock like hornstone, and on a knoll to the E. of this road are purple felstones, whose clearly developed banding shows a S.W. strike with a prevailing S.E. dip.

* I adopt this term from Prof. Bonney, Quart. Journ. Geol. Soc. vol. xxxv. p. 322, note *.

At Flax-Hill quarry, S.W. of Wrockwardine, the purple-banded felstones are highly spherulitic. A dyke of earthy rock, a decomposed greenstone, throws off the lavas towards the S.W. The felstone is continued for some distance to the S.W., and is seen at Leaton, one mile S.W. of Wrockwardine.

At about one mile S.S.W. of Wrockwardine, midway between Burcot and the old turnpike on the Shrewsbury road, some very interesting rocks are exposed. They are very hard and compact, approaching hornstone in texture and fracture, but are clearly fragmental. The contained fragments are green and purple felstone, the purple variety being sometimes banded. They vary in size from a pin's head to a pigeon's egg. Their shape is irregular, their outlines being sometimes well defined, but often shading off into the matrix, which is frequently as compact as hornstone. This rock has seemed to me to favour the clastic origin of hornstone. The beds have a high dip to the W. Associated with this breccia is a compact fine-grained rock, to which also Prof. Bonney assigns a fragmental origin (Note 2, p. 666). Underlying these strata, in the field to the E., is purple felstone (Note 1, p. 666).

At Lea Rock, about half a mile W. of the last spot, are the banded felstones or altered perlites described by Mr. Allport in the Journal of this Society *. Nuclei of quartz, chalcedony, and agate give the rock a peculiar spotted aspect. The nuclei sometimes open out into geodes lined with quartz crystals.

The induration which these and other rocks of the Wrekin area have undergone is due, I conceive, not to intense heat (for the rock, when in contact with intrusive masses, by no means displays greater hardness), but to the chemical action of infiltrated waters at perhaps very low temperatures. The dissolving power of water is well seen in some of the banded felstones, free silica being dissolved out and deposited in lines of minute quartz crystals along the lines of lamination. I have also noticed in the quartzites that weathered surfaces constantly display a coating of recrystallized quartz. The dissolved silica may well have acted as the cement to the flinty hornstones and breccias.

Summary.—A low rounded elevation, trending S.W., composed of purple and green felstones and hornstones, with some highly indurated agglomerates, and broken through at intervals by greenstone. Bedding not very clear, but a general S.W. strike, agreeing with the strike of the mass, but discordant to the usual strike of the Wrekin chain.

7. *Charlton-Hill area.*

Details.—Charlton Hill is an inconspicuous oblong elevation, three quarters of a mile from N. to S. and half a mile from E. to W. The northern half is composed of tuff of the Lawrence-Hill type. This passes down towards the S. into a massive bed of conglomerate (Note 3,

* Vol. xxxiii. p. 454.

p. 667) striking across the centre of the hill from E. to W., and dipping to the N., that is, with the normal dip and strike of the Salop Precambrian rocks. The contained pebbles are well rounded; they consist of quartzite, quartz, gneiss, mica-schist, red felspar, and granitoid rock. This assemblage strongly suggests derivation from the Malvernian series represented at Primrose Hill*. The matrix is apparently ash. This bed is indisputably a subaqueous formation; it appears to be on the same horizon as the tuffs of the Wrekin. Following this conglomerate along the strike to the E., it is seen to end abruptly against a reddish felspathic rock, probably intrusive.

Below the conglomerate, and occupying the south end of the hill, is a rock which I have observed in no other Shropshire locality. It is a mass of porphyritic felstone, composed of crystals of red and green felspar in a dark green matrix. The hill at this point is flanked by quartzite.

There is a fine exposure of Precambrian rock in the road S.E. of Charlton Hill. In the upper part is a compact red felstone; below this are beds of greenish claystone, with gritty bands, made up of small rounded fragments similar to the pebbles of the chief conglomerate, the prevailing constituents being quartz and a red felspar. These seams of grit have all the appearance of derivation from the same land as the conglomerate, but from a greater distance, the pebbles being much smaller and being more exclusively composed of the less destructible rocks. A little lower down the road is an instructive junction of the older Precambrian beds with the overlying quartzite, which dips S.S.E. at 60°.

In a small boss to the S. of Charlton Hill is an indurated tuff of the ordinary Wrekin type, associated with gritty beds. Quartzite dips away to the south.

Summary.—Conglomerates, grits, claystones, and tuffs, with a general dip to the N.; felstone, sometimes porphyritic; quartzites dipping away from bosses of the older series in all directions.

8. *District between the Wrekin and the Lawley.*

The two areas are connected by a south-west line of fault. On this line igneous rocks are exposed at two points. The first is in a cutting on the Severn Valley Railway, near Cound Cottage, about a mile south-west of Dryton Bank. The rock is a dark brownish-green fine-grained dolerite, with amygdaloids of calcite. The other spot is a mile and a half further to the south-west, where a small quarry has been opened, on the opposite side of the ravine from the great sandstone-quarry of Cound Moor. Here also the rock is a greenstone; but it is more coarsely crystallized, the felspar and the augite (or hornblende) being readily distinguishable. Higher up on

* In this conglomerate I have made out eighteen varieties, more than half of which I have recently recognized in Anglesey.—C. C., Sept. 1879.

the slope of the hill this greenstone is overlain by beds of Caradoc sandstone.

9. *The Lawley.*

Details.—The centre of the hill is a mass of greenstone. At the summit is a dark-green basalt. On the north-west slope the rock is coarsely crystalline, and is very similar to the greenstone opposite Cound-Moor quarry. The crystals of white felspar imbedded in a dark-green matrix give the rock a speckled appearance. In parts, where the greenstone is decomposed, mica and cubic iron pyrites are seen. Following the ridge towards the north-east from the summit we come, above Yew-Tree House, to a grey felspathic breccia, which is continued for some distance to the north-east extremity, where coarse tuff, striking east and west in bands across the ridge, is broken through by black basalt. At the south-west end a red felsitic rock occurs.

The Lawley is bounded by faults on both sides. On the west lie the Coal-measures of Leebotwood; on the east runs a parallel valley excavated in Shineton Shales. At the south-west end quartzites are seen dipping away from the hill, and lapping round for some distance to the east and north-east. Just below the quartzite at Cowley Farm, where the ridge breaks down into the ravine to the south-west, is a small exposure of grey grit with Caradoc fossils. The strange position of these beds will be perceived when it is observed that this fragment is separated from the Caradoc escarpment of Hoar Edge by an intervening ravine hollowed out in upper Cambrian rocks (Shineton Shales).

Summary.—A south-west ridge, composed of an intrusive mass of greenstone, with Precambrian tuffs and felstones at each end, lapped round by quartzites on the south-west and south, and bounded by faults on all sides.

10. *Caer Caradoc.*

Details.—The N.E. spur, called Little Caradoc, is mainly composed of intrusive rock. At the north-eastern extremity is a mass of greenstone extending for several hundred yards along the ridge; it is large-grained, the plagioclase prisms sometimes reaching nearly an inch, and is strongly distinguished from every other greenstone in the district. Resting on it to the S.W. are some slaty beds of a flinty texture; they are of slight thickness, and are disturbed by the intrusion of the greenstone. The remainder of Little Caradoc is chiefly composed of fine-grained greenstone.

In the neck uniting this spur with Caer Caradoc proper the greenstone is highly altered; it is spotted with spherical concretions of radiated epidote. In some of the nuclei calcite is crystallized with the epidote. A similar rock extends for some distance along the ridge towards the summit. Quartz is sometimes substituted for the calcite in the amygdaloids.

The structure of the main mass is very varied. At the summit, where the remains of an ancient camp are visible, is a light-coloured

reddish felspathic rock, apparently a felstone, mottled with minute geodes of quartz, which is sometimes coated with viridite. The geodes show a tendency to lie in parallel planes, as if they had originally been air-bubbles in a lava-flow. To the S.W. of the summit greenstone breaks out in the centre of the ridge, and keeps to the crest of the hill for some distance, being flanked on each side by grey felspathic rocks. Then the grey rock occupies the entire saddle, but greenstone soon reappears, and forms the axis of the range for a quarter of a mile, with the grey rocks, as before, on each side. An isolated boss of greenstone also breaks out on the S.E. slope. Towards the S.W. end of the range is a very interesting series of bedded rocks, clearly dipping to the N.E., that is, at right angles to the trend of the ridge; they are undoubtedly fragmental and most distinctly stratified. Some of the beds are very thin. In some spots several varieties occur in a thickness of a yard. The common rocks are a coarse ashy shale, a coarse grit made of crystals of red felspar with grains of quartz, a similar grit with the fragments imbedded in a dark matrix (Note 4, p. 667), a felspathic breccia, and a compact felspathic rock with a flinty fracture. In one place I detected a thin band of quartzite, the only instance of the occurrence of that rock in the older Precambrian strata of the district. The Caer Caradoc range terminates with a mass of greenstone, which occupies the south-western slope, and by its intrusion has increased the dip of the overlying beds.

On the Survey map this mountain is coloured as altered Caradoc, with four masses of intrusive greenstone irregularly arranged. The position of these intrusions, as well as the description of the bedded rocks, requires some modification. There are more than four eruptive masses, and they are generally arranged in a linear manner along the crest of the ridge.

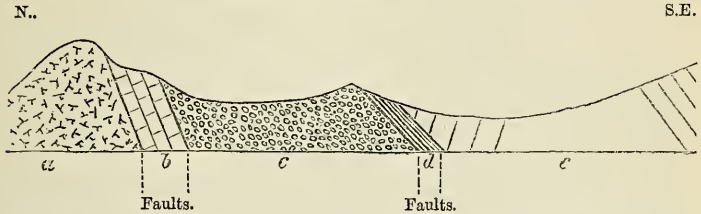
The strikes in this range have been greatly disturbed by the greenstones. Wherever bedding can be made out in proximity to eruptive rock, the dip is away from the intrusive mass. On the whole it is probable that the original strike was in accordance with the prevailing E. & W. strike of the axial series. At the S.W. end, for example, where the bedding is most distinct, the dip is N.E.; but it is evident that if the intrusive boss which has disturbed the beds at that point did not exist, the dip would have been more northerly.

Caer Caradoc, like the Wrekin, is a wedge of consolidated Precambrian rock, thrust up through younger beds, and is consequently bounded by faults on all sides. In the Survey map, Wenlock strata are faulted down against the N.W. side of the ridge. This is quite correct as regards a part of the distance; but this Wenlock wedge has been carried by the surveyors too far to the S.W. Towards the S.W. end of the hill the fault brings down against the axial rocks the slates of the Longmynd group, with their usual dip to the N.N.W. at a very high angle. On the S.E. side of the ridge the relations of the flanking strata are very complicated. At Little Caradoc the axial rocks are overlain by high-dipping quartzite, succeeded by Hollybush Sandstone and Shineton Shales, with Caradoc

Sandstone plunging towards the latter. Fig 6 illustrates this arrangement.

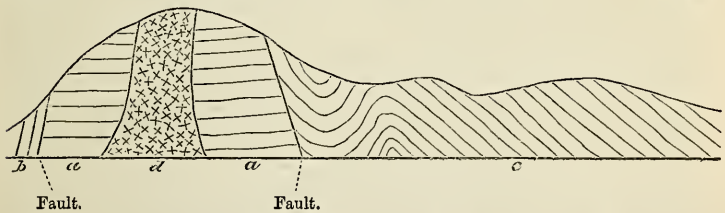
I believe the junctions of these flanking rocks to be faults in each case, the masses being sliced out of more extensive formations. These slices rapidly thin out towards the south-west, so that Caradoc sandstones gradually approach the axis, and, under the summit of the hill, they rest against it. Fig. 7 represents the relations of the flanking rocks at the south-west end of the mountain.

Fig. 6.—*Section across Little Caradoc and valley to the South-east.*
(Length of Section about half a mile.)



a. Greenstone of Little Caradoc. *b*. Quartzite. *c*. Hollybush Sandstone.
d. Tremadoc (Shineton Shales). *e*. Caradoc.

Fig. 7.—*Section across Caer Caradoc towards its South-west end.*
(Length of Section about 1 mile.)



a. Precambrian Rocks. *b*. Longmynd Slates.
c. Caradoc Sandstone. *d*. Intrusive Dolerite.

Summary.—Caer Caradoc is a wedge of rock limited by faults striking S.W., composed of felspathic grits, felstones, ashy shales, and indurated claystones, which are locally disturbed by several protrusions of greenstone arranged in a line along the axis. On the N.W. the hill is bounded partly by Wenlock limestone and shale, and partly by Longmynd slates; on the S.E. by quartzite, succeeded by Hollybush Sandstone and Tremadoc Shales at the N.E. end, and by contorted Caradoc Sandstone for the remainder of the length.

11. *Helmeth Hill.*

This low narrow ridge continues the line of Caer Caradoc for a

short distance to the S.W. A green felspathic rock is seen at one spot on the S.E. slope.

12. *Hazler Hill.*

A greenish breccia occurs at the north-east end, near the road to Church Stretton. A similar rock is seen at the south-western extremity, where it is associated with a dark compact felstone. Here sets in a mass of greenstone, which forms the crest of the low ridge connecting Hazler with Ragleth. This rock is well seen in a quarry at the side of the road. In places it is spotted with amygdaloids of calcite.

13. *Hope Bowdler and Cardington range.*

Details.—At the most westerly summit, called the Gaer Stones, the prevailing rock is grey, earthy, rather compact claystone. A similar material also occurs as the matrix of a grey breccia. On the slope to the E. of the crest is a rough grit of red felspar and quartz fragments, the former predominating.

Following along the ridge to the E., we come next to Hope-Bowdler Hill. Here also the rock is for the most part fragmental. Several varieties of breccia occur, the fragments being of quartz and felspar, and the matrix presenting a very ashy appearance. This breccia thins out towards the E.

On the southern slopes of Cardington Hill, at a lower horizon than the clastic beds, is a fine development of green and purple felstone, the latter predominating. This rock is magnificently exposed in the crags overhanging the gorge which runs up from near Woodgate into the heart of the ridge. It is compact in texture, with scattered felspar crystals, and is banded and spotted with darker colours (Note 5, p. 667). It is limited below by a bed of grit to be shortly described; and, as there are no signs of disturbance either above or below, I infer that it is not intrusive. In the mouth of the ravine, the Survey has assigned to the purple felstone a dip towards the S.; but I am by no means certain that the alleged bedding is not due to jointing. Towards the E. this felstone band approaches nearer and nearer to the overlying quartzite of the Sharp Stones through the thinning out of the breccia.

To the S.W. of this gorge, on the farm of Woodgate, is one of the clearest sections of the entire Precambrian series. The succession, taken in ascending order, is as follows:—

(1) Grey felspathic grit, much kaolinized; 7 to 8 feet.
(2) Purplish felstone, compact, with small felspar crystals disseminated, weathering white at surface; 15 feet.
(3) Speckled grit (Note 6, p. 668), composed of grains of white felspar kaolinized, of small crystals of red felspar, and of green chlorite (?) in scales (which sometimes display a striated "slickenside" surface), and disseminated through the mass; very small rounded pebbles occasionally occur; the white and green minerals form alternating laminæ; barium sulphate is seen in small nests and veins: 20 feet.
(4) Purple felstone, passing up into the mass previously described.

The section displays a very clear dip to the N. at 80°.

About half a mile to the E. of Woodgate, near the farm of Underhurst, is an exposure of a granitoid rock, not unlike the imperfect granite of Primrose Hill, but containing more chlorite.

On the W. side of the main axis, whore the Cardington promontory springs from the side of the chain, Longmynd slates (coloured "Caradoc" by the Survey) are faulted down against the Precambrian rocks of Helmeth and Hazler Hills. On the east, tho spur projects into an area of Caradoc Sandstone. Near the village of Cardington, the rocks just described are overlain by bedded quartzite, forming the Sharp-Stone ridge, and dipping N. at a high angle with a striko of half a mile. The older series and the quartz rock together form the promontory, which is surrounded, except at its neck, by Caradoc Sandstone with its normal S.W. strike.

Summary.—A great spur, with an E. and W. strike, projecting from the E. side of the main chain at Hazler Hill, composed of breccias and grits in the upper part, underlain by massive felstone with alternations of altered grit and felstones below, and red granitoidite at the base, the whole dipping at a high angle to tho N., thrusting up quartzite in front, and being surrounded by Caradoc Sandstone with its usual S.W. strike. Longmynd slates faulted down against the W. flank of the main ridge.

14. *Ragleth Hill.*

Details.—This elevation is coloured on the Survey Map as altered Caradoc, with a linear mass of "greenstone" running about halfway along the crest from the N.E. end. This "greenstone" has no existence, the ridge being occupied by a compact greenish-grey claystone, which also makes up the chief mass of the north-easterly half of the mountain. On the S.E. slope, midway between each end, are beds of thinly laminated greenish fine-grained slate, very similar to ordinary Longmynd slate, and displaying the normal dip (W.N.W.) of that formation. This coincidence of dip is apparently due to a local protrusion of a highly altered greenstone which breaks out of the side of the hill at this point. The slaty beds are overlain by compact reddish felstone. At a little distance to the W., similar slate is interstratified with a coarse felspathic grit with a few grains of quartz. Towards the south-west end the grit appears with an E. and W. strike, associated with a grey compact claystone (Note 7, p. 668). Alternations of slaty and brecciated bands are seen. At the extremo S.W. end is a fine-grained grey claystone in thin beds dipping at a high angle to the N.N.E. A little to the west of this spot is a knob of dolerite, containing much free calcite, and breaking to the surface at about tho line of fault between the Cambrian and Precambrian rocks. This protrusion appears to have produced the deviation in tho strike of tho claystone from the normal E. and W. direction.

Caradoc rocks bound the S.E. side with a faulted junction; they also lap round the S.W. end, whero they dip to the S. They aro underlain by a coarse conglomerate with a S.W. dip. This rock is

chiefly made up of pebbles of quartz, and contains flakes of silvery mica, apparently due to subsequent alteration.

In the N.W. side of the hill, the fault brings down Longmynd strata against the Precambrian axis. The slates which rest against Hazler Hill are continued for about one third of the length of the Ragleth, when they suddenly give place to the purplish felspathic sandstones which lie in force to the S.W. The relations of these subdivisions of the Longmynd series are not yet fully known, and do not concern our present purpose.

Summary.—A S.W. ridge composed of claystones and felspathic grits; a W.N.W. dip, due to a greenstone protrusion on the S.E. side, and a N.N.E. dip at the S.W. end, with another greenstone mass a short distance to the W.; Caradoc rocks faulted against the S.E. side and lapping round the S.W. end; Longmynd slates and sandstones faulted down on the W.N.W.

15. *Wartle-Knoll Group.*

East of the farm named Carwood is a small conical knob composed of brownish felstone full of closely approximated joints (Note 8, p. 668). Wartle Knoll, a loftier elevation, is chiefly made up, especially in the centre, of a breccia of quartz and felsitic fragments. Felspathic rocks of an obscure character are found on the slopes. The Carwood mass is coloured as Caradoc by the Survey. Its position on the S.W. axis, together with its resemblance to some of the Precambrian volcanic series, renders its Precambrian age almost certain. Wartle Knoll rises up through Longmynd strata, and is coloured as such on the Map; but on the whole it resembles Precambrian rather than Cambrian rock.

The Precambrian axis is evidently continued under the purple Longmynd sandstones of Hopesay Common, and underlies an anticlinal of Caradoc rocks at Corston, two miles S.W. of Wartle Knoll.

16. *Kington Group.*

Hanter Hill is composed of gabbro on the E. side and dolerite at the summit. On its N.E. slope is a small exposure of a grey granitoid rock (Note 9, p. 668).

Stanner Rock contains similar dolerite and gabbro. In about the centre of the ridge is a grey compact felstone. At the N.E. end is a dark grey grit with obscure E. and W. bedding, and near it to the S. is a quartzose breccia. In the same locality is seen a greyish granitoid rock, similar to the specimen at Hanter Hill. The structure of this ridge suggests that of the Lawley.

I refer this group with hesitation to the Precambrian period. The rocks are brought up on the same axis of upheaval, but the lithological resemblances are not at present very decisive. The greenstones are, of course, eruptive and posterior.

C. Evidence for Precambrian Age.

1. *Stratigraphical.*

It will be sufficient to collect a few of the facts detailed in the previous sections.

On the S.E. side of the Wrekin the proof is very clear. The axial rocks, striking W.S.W., are overlain by quartzites striking to the S.W. The quartzites are succeeded by the Hollybush Sandstone, and the Hollybush Sandstone by the Shineton Shales (Tremadoc). The Hollybush must thus be of, at least, Upper Cambrian age; the quartzites must be of, at least, Lower Cambrian age (they are probably Precambrian), and the volcanic series must be Precambrian. The discordance between the axial and the flanking rocks will be still more evident when the dips are compared. The volcanic series dips N.N.W., while the quartzites dip S.E. A greater unconformity could hardly be imagined. These relations are expressed in figs. 2, 3, and 5.

In Caer Caradoc the sections are still more satisfactory. Undoubted Lower Cambrian rocks, the Longmynd series, are brought down against the N.W. side of the axis, the discordance of strike between the two formations approaching a right angle, the Precambrian beds dipping northerly, the Longmynd slates westerly (see fig. 7). These Lower Cambrian rocks probably hold the same relation to the axis on its N.W. side as far to the N.E. as Wrockwardine, or even to Lilleshall, being masked by a thin covering of Carboniferous strata at the N.W. base of the Lawley, and by Triassic deposits in the Wellington district.

The Wrekin and Caer Caradoc chain is the axis of a great anticlinal. The formations dip away on both sides, and their dip is determined by the upheaval of the Precambrian nucleus. But the axial rocks themselves do not share in the anticlinal arrangement, being wedges of stratified rock thrust up, after consolidation, between parallel faults. This peculiar method of mountain formation is paralleled in the Malvern chain and in the Dimetians of St. Davids. I have elsewhere* described this structure as "plagioclinal."

2. *From included fragments.*

In the middle of the Longmynd series of Haughmond Hill, near Shrewsbury, is a great bed of conglomerate†, coloured "greenstone" on the Survey Map. It commences a hundred yards or so E. of the Castle, and runs in an unbroken line for more than a mile to the N.N.E. Its superior hardness gives it in some places a somewhat mural appearance. It is made up of rounded pebbles cemented in an ashy-looking matrix. Amongst the pebbles I recognize a grey

* Geol. Mag., May 1879.

† I have already used this argument in the 'Popular Science Review,' January 1879.

hornstone, like one of the Lilleshall rocks, and a chocolate felstone with a few scattered prisms of felspar, very similar to some of the Wrockwardine types. This conglomerate shades off gradually, both above and below, into the ordinary Longmynd sandstones. There is little doubt that this band has been derived from the series described.

I have already mentioned that on the N.W. flank of the Ragleth and further to the S.W., the Longmynd series is represented by a felspathic sandstone. This rock is chiefly made up of quartz and a red felspar, and it is highly probable that it has been produced by the degradation of the granitoid series.

In my paper "On the Quartzites of Shropshire" (Q. J. G. S. xxxiv. p. 760), I state that "towards its base the quartz-rock contains fragments derived from the older series, consisting of small rounded or unrounded pieces of felstone greatly decomposed, but in some cases showing distinctly the banded structure characteristic of some of the Wrekin felstones." As the quartzite is of (at least) Lower Cambrian age, the felstone must be Precambrian. Professor Bonney has examined some of these specimens, and he quite confirms my previous opinion (Note D, p. 666).

General Summary.

1. The axial chain of hills in South Shropshire must be removed from the category of intrusive greenstones, and regarded as built up of bedded rocks broken through by later basic eruptions.

2. The chain is flanked by various formations from the Lower Cambrian to the Trias. Some of the flanking deposits, which are of (at least) Lower Cambrian age, are partially or wholly derived from the axial rocks. By the double test of stratigraphical position and included fragments the bedded part of the chain is thus shown to be of Precambrian age.

3. The lithology of the chain is very varied. (1) Metamorphic rocks of Malvernian (the author) or Dimetian (Professor Bonney) type. (2) Volcanic (Mr. Allport, Professor Bonney, and the author). (3) Sedimentary, as conglomerate, grit, claystone, and shale.

4. The separate masses composing the chain are wedges of the solidified crust thrust up through younger deposits between great parallel S.W. faults. The structure of the ridges is plagioclinal (the strikes being across the axis), and their direction is determined by the faults.

Notes on the Microscopic Structure *of some* Shropshire Rocks.

By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

At Ercal Hill, to the north of the Rhyolites of the Wrekin, so admirably described by Mr. S. Allport*, is a mass of reddish granitoid

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 449, &c.

rock. Microscopic examination of a slide of this caused me to suspect that it was not a true granite, even before the investigation of Dr. Callaway's specimens and our joint visits to the locality. Besides the granitoid rock, there is seen, in the lower portion of a large pit, a compact greyish rock; both these have here been very fully examined with the following results:—

(A) *Compact type.*—Five specimens in all have been examined, three from different parts of the greyish mass forming the lower portion of the pit, two from its upper left-hand corner, where the rock has a redder colour and a very fragmental aspect. As regards the first three, under the microscope they possess in common far more resemblance to the rhyolites described by Mr. S. Allport than one would suspect from their macroscopic aspect *. All, seen by transmitted light, have a more or less glassy aspect, and with crossing Nicols exhibit the usual devitrified structure. For the details of this I content myself with referring to Mr. Allport's descriptions, and will merely call attention to the structural variations in each specimen.

(1) A compact buff-grey rock from the base of the quarry ("fairly typical, very jointy"—C. C.). This exhibits a great number of somewhat faintly defined crystallites of a rather curved or wavy form, such as are figured by Zirkel in the S.E. corner of figure 4, plate viii. "Microscopical Petrography" (U.S. Geol. Explor. of Fortieth Parallel), which give slight indications of a fluidal arrangement: and there are numerous minute filmy brown patches of what may be an iron mica, both isolated and in clusters, associated with a fibrous mineral showing with crossed Nicols a bright golden colour; minute fibres of the same are disseminated over the slide. The white specks visible in the rock are probably decomposed felspar; the only one, however, on the slide shows spherulitic structure towards the exterior, and may be simply a fragment of glass. There are one or two included fragment-like bits containing much opacite †.

(2) A dull green rock, marbled or spotted with pinkish buff, from the upper part of the mass. General character fairly similar to last, except that in parts a fluidal structure is more conspicuous, and there are abrupt changes in the microlithic structure, with comparatively sharp lines of division, as is common in glassy rocks; cracks traverse the slide, filled now with microlithic minerals, chiefly quartz; some of the spots, as in the last, are probably fragments in a slightly different condition.

(3) A marbled dull greenish and pale-red rock, also from the upper part of the grey mass ("taken from a place where there is a marked concentric spheroidal jointing"—C. C.).

Parts of this slide exhibit a beautiful perlitic structure; other

* The marked difference in colour is due to the fact that the normal Wrekin rocks are full of disseminated opacite and rich red ferrite, while in these from the Ercal the corresponding mineral is a pale-brown ferrite.

† This pseudo-clastic character, the result, doubtless, of motion after partial consolidation, is not uncommon in glassy rocks. Mr. Allport has given me a most interesting example of it from the other part of the Wrekin.

parts groups of spherulites, with radial structure, some being about ·03 inch in diameter.

To avoid repetition it is enough to refer to Mr. Allport's descriptions and plate (*loc. cit.* pl. xx.)*.

(4) and (5) are taken from the upper part of the pit on the left-hand side. They are much redder in colour than the others, are more like the granitoid rock, and have a very fragmental aspect. A glance, however, at the slides under the microscope shows that they exhibit the usual aspect of a devitrified glass, with a rather brecciated structure, of the character already described, both specimens showing indications of fluidal structure. In the one this is very clear; in the other, more or less perfectly developed spherulitic structure in frequent. After a careful study of these various slides, and comparison of them with my collection from other parts of this district, I have no hesitation in asserting that the compact rock of this pit is only the Wrekin rhyolite somewhat altered by various subsequent chemical changes, and that it must be regarded as intrusive in the granitoid rock.

(B) *Granitoid type.*—Of this I have had five slides prepared from specimens taken from various parts, from the lowest to the highest exposures. All may be described as consisting mainly of quartz and felspar, with a little iron peroxide (species uncertain) and a very small quantity of chlorite (?). The quartz contains many very minute enclosures; the felspar is rather decomposed, and stained with ferrite; orthoclase and plagioclase (? oligoclase) are both common; and there is much cross-hatching and interbanding visible. Some grains rather resemble microcline. Indications of graphic structure, especially on a minute scale, are not rare. As regards the specimens from the middle part of the mass, I cannot venture to express a positive opinion; they are very like a variety of granite, and yet there is a something, impossible to express in words, which reminds me rather of the granitoidites of the "Dimetian" series in Wales than of true granitic rocks. The specimens, however, from the bottom part of the mass (as may even be seen by the unaided eye) are certainly clastic. Rather rounded fragments, consisting of quartz and felspar, often exhibiting a minute graphic structure, are imbedded in a matrix containing smaller fragments of quartz, often distinctly angular, and of felspar; the matrix also appears to be composed of these two minerals, in an extremely fine state of division, but often showing an approach to graphic structure. One of two explanations is alone possible: either the granitoid rock has been crushed *in situ* (owing probably to the intrusion of the rhyolito); or we have here a quartz-felspar grit, which, though highly metamorphosed (the more finely divided constituents having crystallized *in situ*), still retains traces of its original structure.

After the best consideration which I can give to the question, I

* I believe this is the first time that perlitic structure has been noted at the Wrekin. Mr. Allport's specimens were all from Lea Rock, where spherulitic structure also is much more common. I have since found specimens in this Ercal pit showing to the unaided eye very distinct spherulitic structure.

incline to the former view. But whether this rock be a granite or a granitoidite (and I believe it the latter), there can be no doubt that it is far older than the rhyolite, and thus we may regard it as, in general terms, a representative of the "Dimetian" series.

(C) A very similar rock occurs at Primrose Hill, just S. of the Wrekin. Two specimens collected by Dr. Callaway, labelled "summit" and "N.W. slope halfway up," in mineral constituents and general character so closely resemble the Ercal rock, that we need not hesitate to class them as belonging to the same series. The former, in structure, is similar to the specimens from the middle part of the Ercal granitoidite; the latter exhibits a clastic structure very distinctly in parts of the slide; so that here also we must suppose a most exceptional case of local crushing or admit a clastic origin.

Gneiss, Primrose Hill.—The slide was cut from a specimen whose banded structure showed even to the unaided eye that it was a gneiss. Microscopical examination proves it to be a most characteristic example: it consists of irregular quartz grains with the interstices often occupied by a granular mineral (of a dull yellowish colour with transmitted light, and rather brilliant tints with crossing Nicols), probably a secondary product and possibly epidote, with felspar, mica, and a greenish chloritic mineral. There is the usual tendency on the part of the different constituents to collect in bands. The rock is not very rich in felspar; some of this is very characteristic microcline. The mica is colourless with transmitted light, and shows very brilliant tints with the Nicols. The green mineral rather resembles chlorite than hornblende.

Gneiss, Primrose Hill.—The specimen was selected as an example of one of the less obviously gneissic varieties. Under the microscope, however, its structure is clearly that of a metamorphic rock. As might be expected from the darker aspect of the specimen, it is poorer in quartz than the last, and has much of a chloritic mineral, not, I think, hornblende, though perhaps replacing it, also some decomposed felspar and a good deal of the epidote-like mineral named above, probably replacing felspar.

Two other specimens from the N.W. side, near the top, are very different. One is a compact dull greenish rock of rather brecciated aspect, the other a cherty-looking rock of a brownish-buff tint. The former appears to consist of rather angular fragments of felspar, with some quartz of variable size, imbedded in an earthy-looking matrix, often dark with opacite, and with some chlorite—a rock of clastic origin, though considerably altered. The other is even more distinctly fragmental; the matrix is earthy-looking and not quite so dark as the other, occupying a larger part of the slide. The fragments, as before, are quartz and felspar; and many of them show a minute graphic or fibrous structure, as exhibited in the above-described specimens, suggesting these as the source whence their materials have been derived.

The specimen labelled "halfway up" is a very different rock. It is of igneous origin, rather finely crystalline, consisting of felspar

and hornblende, both rather decomposed, with a little iron peroxide and chlorite. The felspar is mainly plagioclastic; but some crystals resemble orthoclase. It is possible that the hornblende may be of secondary origin; but the rock can now only be defined as a diorite. It is not unlike one of the "traps" from Malvern in my collection.

(D) *The Quartzites.*—The first specimen, from "near the cottage on the Wrekin," and thus from quite the lower part of the quartzite series, contains numerous rather angular fragments, some $\frac{1}{3}''$ long, of a material like decomposed pumice. Microscopic examination shows that the rock consists of well-rounded quartz-grains and fragments of varying size, some rounded, but most rather angular, of a rather decomposed rhyolitic rock, doubtless that of the Wrekin. One fragment still exhibits perlitic structure. There is but little cementing material, and this appears to be quartz. The quartz-grains are pretty full of very minute enclosures, and bear a strong resemblance to those of the granitoid rock described above.

There is a point of general interest in this rock worth noting, namely, that the quartz "cement," which is obviously of secondary formation, is often deposited so as to form one crystal with that in a grain (proved, of course, by their giving the same tint with crossing Nicols). The boundary of the grain, however, is clearly shown by the cessation of enclosures, from which this secondary quartz is remarkably free.

The second specimen is from "section S.E. of Charlton Hill." It consists of similar quartz in smaller grains, and finer fragments (often almost triturated and acting as cement) of a rock which appears to be rhyolite. The third specimen, "W. of Rushton, N.W. of Wrekin," is rather coarser than this; of the presence of the rhyolitic rock here, though in smaller grains than in the first, there can be no doubt: some of the quartz is very full of enclosures. Magnified about 70 diameters, they appear as dusky specks, about 200; some remain opaque, but most prove to be cavities of variable form, in the larger of which I sometimes detect very minute bubbles, but cannot distinguish any in the smaller. Some of the grains themselves exhibit a compound structure, as if derived from an older quartzite.

(1) *East Field, near Burcot.*—A glassy-looking rock, with wavy irregular lines of opacite and ferrite, indicating a fluidal structure, and occasional well-preserved felspar crystals, with rather broken edges. Both orthoclase and plagioclase can be recognized; with crossed Nicols a minute cryptocrystalline structure is visible, a considerable part of the slide being dark. The basis has once been glassy, and, so far as can be ascertained, a portion yet remains undevitrified. The rock appears to an old rhyolite of the Wrekin type.

(2) *Burcot, Wrockwardine.*—The microscopic structure of this rock comes rather near to that of no. 5, and it is not without hesitation that I place this among the sedimentary. The mineral composition, however, is, I expect, not very different. Parts of it with crossed Nicols show a very similar structure; but the aspect of this

is more distinctly fragmental, and the bands of ferrite and opacite, with which occasionally occur slightly larger fragments of felspar and quartz, give the rock, as in the hand specimen, the appearance of one banded by deposition rather than by flow. It might be formed of the finest dust of such volcanoes as produced the Wrekin rhyolites, or by the denudation of such rocks.

(3) *Charlton Hill.*—This rock consists of well-rounded fragments in a matrix which resembles a mixture of decomposed felspar and chlorite. Among the fragments I recognize the following varieties:—(*a*) a fragment of very typical granitoidite with characteristic quartz, finely banded plagioclase, and a mica (? paragonite); also one or two smaller fragments, possibly of the same rock; (*b*) a rock apparently consisting of decomposed felspar and chlorite, in general appearance rather like diabase, probably a schist; (*c*) a rather schistose fragmental rock, consisting of quartz, chlorite, and decomposed felspar; (*d*) a rock having a fine granular ground-mass, with some viridite pseudomorphs, some nests of quartz, with viridite and (?) epidote, origin doubtful, but probably clastic; (*e*) a quartzite; (*f*) a quartzose rock, consisting of long angular quartz fragments in a rather fibrous fine-grained matrix, containing probably a little of a chloritic mineral.

(4) *Caradoc.*—This rock is undoubtedly clastic, though at first sight it resembles, to the eye, a fine-grained granite. The fragments are more or less rounded and about equal in size; they compose the greater part of the rock, the interstices being occupied with a finely granular rather earthy-looking matrix. Quartz predominates among the fragments; it contains the dusky-looking enclosures, which show an approach to a linear arrangement rather characteristic of the older rocks both here and in Wales; there is a fair amount of felspar, much of it orthoclase, showing sometimes a cross-hatched structure (? a little microcline), and some plagioclase. Some of the felspar is very full of enclosures; we find also fragments of a brown glassy-looking rock, some of which show fluidal or spherulitic structure, and closely resemble the Wrekin rhyolite. There is a good deal of scattered ferrite and opacite, with mieroliths of chlorite, epidote, and apatite (?). The appearance of the slide induces me to believe that its material has been derived from the rhyolitic and granitoid Wrekin rocks.

(5) *Hope Bowdler.*—A base, apparently glassy, but rendered almost opaque by ferrite staining, and crowded with acicular felspar microliths. Several larger crystals of felspar are scattered about the slide, both plagioclase and orthoclase being, as usual, recognizable; they are very full of microlithic products, ferrite, minute enclosures of dark glass (?), &c., also a few grains of a greenish mineral, probably decomposed augite or hornblende. One crystal shows the characteristic cross section of the former; needles of apatite are sometimes associated with these. There are, as usual, larger grains of iron peroxide. The slide exhibits numerous darker patches with well-defined rounded outline; these seem to correspond in all respects with the rest of the slide, except that they are coloured by a black, instead of a brownish peroxide of iron.

(6) *Woodgate quarry.*—Rolled and subangular fragments of quartz, decomposed felspar, grit, and rhyolite or mudstone. There is also a large quantity of a streaky chloritic mineral, and many of the fragments appear to be stained with ferrite. Parts of the slide present some resemblance to organic structure, such as sponge-spicules; but, after repeated examination, I believe that they are rhyolitic fragments with crystallites of the form mentioned above (p. 663).

(7) *S.W. slope of Ragleth.*—This rock, which, macroscopically, appears to be a compact yellowish-grey mudstone with a few lighter spots, exhibits under the microscope a minute confusedly granular structure, being apparently composed of fine felspathic mud, stained with ferrite, in patches more or less irregular and containing a fair amount of opacite. Some rather acicular doubly refracting microliths may be of secondary origin, as are the felspathic (?) infiltrations of a crack. There is nothing characteristic about the rock, which might be of any age from Silurian downwards.

(8) *E. of Carwood*—This rock is a good deal decomposed; it appears to have undergone some brecciation *in situ*, and to have been recemented, quartz and epidote occurring in the cracks. It might be a decomposed rhyolite with a faintly marked flow-structure, or it might be an altered mudstone, the detritus of a rhyolite. I hesitatingly incline to the former identification.

(9) *N.E. of Hanter Hill.*—The specimen consists of quartz, felspar, a little of a chloritic mineral (probably replacing hornblende or biotite), and ferrite. The quartz is full of minute enclosures, which give it, in parts, a dirty aspect. These, on applying a high power, appear opaque, being probably earthy or ferruginous; others, however, are transparent,—whether cavities or microliths of some mineral I cannot with certainty determine; some show a very minute black speck, as if they were nearly full of a fluid. The felspar is much decomposed; probably it is chiefly orthoclase, but the characteristic banding of plagioclase is also visible. The rock is evidently of fragmental origin, one part of the slide showing many small grains and rather a different structure from the rest; but it has been a good deal altered, and in general aspect recalls specimens of the granitoid Dimetian rocks which I have examined.

West Field, Burcot.—A rhyolitic agglomerate, apparently wholly composed of volcanic material. Some of the larger fragments exhibit different varieties of fluidal structure, and one shows excellent perlitic structure.

Lilleshall.—Two specimens, collected by myself about two years since, have been examined; one (from the top crag on the S. flank of the ridge) is a rhyolitic agglomerate, like, but rather more decomposed than, those at the Wrekin described by Mr. Allport*. The other is a rhyolite (devitrified) with rather obscure indications of spherulitic structure. It occurs just S. of the monument, and is probably part of a small *coulée*; but its relations to the other rocks are not very clear.

As the result of the investigations above described, I should con-

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 458.

clude, from microscopic evidence alone, irrespective of that obtained in the field, that the granitoid series was much older than the other rocks, and that materials from it, together with fragments from the rhyolitic series, had been worked up into several of the later clastic rocks. It is remarkable that we find here in Salop, as in Caernavonshire, a metamorphic group and a felsitic group (with considerable similarity in each case) in apparent sequence, yet with marked difference in age. Some of the Primrose-Hill specimens also rather resemble certain other rocks recently described by Dr. Hicks, more especially from St. Davids*, and by him grouped with the Welsh quartz-felsites under the name Arvonian.

Discussion.

Dr. Hicks spoke of the extreme interest of the paper, and the confirmation it furnished of the views he had already expressed. He thought that probably at least three groups would be found in this region also. It was also interesting as showing that the granitoid series had a different strike to that overlying it.

Prof. Hughes wished to ask if the stratigraphical relations of the rhyolite and the granitoid rock had been observed in the field, or were only inferred from microscopic examination; and whether the discordant strike had been observed on the same side of the fault.

Prof. Bonney said the rhyolite was clearly intrusive in the granitoid series; and mentioned some points of interest connected with the microscopic examination of the rocks, which he had described in an appendix to Dr. Callaway's paper.

Dr. Callaway said that he had only been able at two or three places to see the granitoid and rhyolitic rocks in contact, and in all cases they seemed to be separated by faults; but there could be no doubt that the granitoid was the older. He had not at present been able to recognize more than two series.

* Quart. Journ. Geol. Soc. vol. xxxv. p. 285.